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AUTHOR Tzeng, Ovid J. L.
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INSTITUTION National Center for Bilingual Research, Los Alamitos, Calif.
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ABSTRACT

In the hope of filling in a missing link for experimental psychologists' research on reading, this paper provides a general review of research on the issue of orthography and its relation to reading. The traditional classification of logographic, syllabic, and alphabetic modes are examined to see how much orthographic variations affect the processing strategy of both beginning and fluent readers. The examination leads to the hypothesis that different cognitive strategies are required to achieve reading efficiency in various writing systems. Issues connected with this hypothesis have been examined by cognitive psychologists, anthropologists, and neurolinguists. Those issues having to do particularly with bilingual literacy are reviewed: (1) reading disability incidence in syllabic and logographic systems compared with alphabetic systems, (2) neuropsychological research, (3) differential processing mechanisms and behavior consequences, (4) the process in reading of recoding the visual input into a speech-like code, and (5) bilingual processing. The research reviewed shows that reading skills acquired in one orthography may not be the same as those acquired in another orthography if these two systems have different script-speech mapping rules. These findings raise questions regarding bilingual reading instruction. (AMH)

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Ovid J. L. Tzeng

September, 1980

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COGNITIVE PROCESSING OF VARIOUS ORTHOGRAPHIES*

Ovid J. L. Tzeng

Introduction

In recent years, reading research has become a significant interdisciplinary endeavor with contributions from such diverse fields as anthropology, artificial intelligence, cognitive psychology, educational psychology, linguistics, and neurolinguistics. The concerns are not only with how the acquisition of reading skill, but also with the behavioral and social consequences involving the ability to become literate in a technologically expanding society. For experimental psychologists, such a revival of interest in reading research has a special meaning.

Historically, the systematic study of the processes involved in reading can be traced back to Wundt's laboratory where sensation, perception, and reaction time experiments became some of the foremost concerns of a newly founded discipline. In those early years, basic reading research was considered to be one of the major tools of analyzing the contents of mind. In fact, shortly after the establishment of the first experimental psychological laboratory, James McKeen Cattell, Wundt's first American student, wrote his dissertation on reading.

In 1908, Edmund Burke Huey published his monumental work, The Psychology of Reading and Pedagogy (Huey, 1908, 1968), in which most of the reading research of this early period was carefully summarized. Oddly enough, soon after the publication of this book, the proliferation of basic research in reading suddenly came to an end and experimental psychologists' interest in mental processes gave way to the analysis and

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specification of the functional relationship between Stimulus and Response in behavioral act. Furthermore, verbal learning experiments in the Ebbinghaus tradition became the focus of research on the analysis of verbal behaviors. Even within the education circle, investigators were preoccupied with a concern for assessment and, as Kolers commented in his introduction to the 1968 reprinting of Huey's book, "remarkably little empirical information has been added to what Huey knew" (Huey, 1908, 1968, p. xiv).

The return of interest in basic reading research was brought about by several important forces. First, the renaissance of the Cartesian idea of "innateness" led by Chomskian transformational linguists shifted researchers' attention from descriptions of surface structure toward analyses of deeper structures in natural languages. Second, advances in computer technology in both hardware and software created a new research technique, namely computer simulations of the higher mental processes such as problem-solving, thinking, and comprehension. Comparisons of such "artificial intelligence" on the one hand and "natural cognitive behaviors" on the other have continued to generate insights into our understanding of understanding.

Third, the psychochronometric procedure (i.e., reaction time experiments), abandoned after condemnation of Donder's subtraction method, has developed to a level of sophistication such that its reliability can be established independently of the stochastical processes involved (Sternberg, 1970; Posner, 1978). Such procedures have proven to be useful for experiments of word recognition, lexical decision, sentence verification, and inferential processes in comprehending texts. Furthermore, reaction time experiments are usually accompanied by complicated models of information processing which attempt to specify basic internal stages as well as their interactions during reading.

Fourth, a great deal of knowledge concerning different levels of speech signals has been accumulated in the experimental analysis of speech perception and production. Such knowledge enables investigators to specify more precisely the script/speech relationship embedded in various writing systems and to examine the role of speech in processing printed materials (Liberman, Liberman, Mattingly, & Shankweiler, 1980).

Fifth, and possibly most importantly, Rudolf Flesch published a book in 1955 called Why Johnny Can't Read. This book had an enormous impact on the public, and the issue of reading problems soon became a national concern. Consequently, federal funds for basic research related to the improvement of education were appropriated by Congress, with the goals of strengthening the scientific and technological foundations of education (Venezky, 1977). Undoubtedly, the availability of financial support plus the cognitive reorientation within experimental psychology will sustain a vigorous pace in basic reading research.

While experimental research in reading is gaining momentum, and rigorous and ingenious experiments are being designed to investigate basic reading processes from letter identification to text comprehension, an important question should be raised: Why has the issue of orthography never been addressed in the discussion of reading and its acquisition? Certainly, English is not the only written script available for reading. People of other languages have been reading other types of scripts which bear very different script-speech relationships as compared to the alphabetic principle of English script. What the effects of these orthographic variations may have on basic reading processes and on the acquisition of reading skills has not been systematically investigated. Conceivably, depending on the level of spoken language a certain type of orthography attempts to transcribe, readers of that orthography may be subject to different task demands. Thus, the only way that we may hope to achieve a full understanding of reading processes in particular and of human cognition in general is through a thorough comparative reading research across different spoken and written languages. It should be

pointed out that in the past, research on bilingual literacy has rarely paid attention to the problems resulting from orthographic differences between first and second languages. This paper provides a general review of the issue of orthography and its relation to reading. In the following sections, I hope to provide a missing link for experimental psychologists' research on reading.

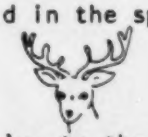
The Issue of Orthography

Ever since Rozin, Poritsky, and Sotsky (1971) successfully taught a group of second-grade non-readers in Philadelphia to read English represented by Chinese characters, the question has been raised repeatedly: If Johnny can't read, does that mean Johnny really can't read in general or Johnny just can't read English in particular? To the reading specialists, educational psychologists, and cognitive psychologists who are interested in the visual information processing of printed materials, such a question is of empirical, practical, and theoretical importance with respect to the understanding of reading behavior.

At the empirical level, there is the question as to whether some writing systems are easier to learn than others. On the applied level, it could be asked if the degree of reading disorders such as dyslexia can be avoided depending on what writing system happens to be used for a certain type of spoken language. At the theoretical level, one must start to untangle the relations between scripts and speech. Research efforts should be directed toward uncovering strategic differences at various levels of information processing (e.g., feature extraction, letter identification, word recognition, etc.) with respect to the reading of different writing systems. These analyses have resulted in a new form of linguistic determinism which emphasizes processing differences rather than production variations (cf. Scribner & Cole, 1978; Tzeng & Hung, 1980).

From the perspective of the acquisition of bilingual literacy, such processing differences due to orthographic variations imply a readjustment of symbol-thought schema developed in learning to read the first language. Whether or not there are differential degrees of difficulty in making adjustments from one type of writing system to another is a question of great importance at both the empirical and the theoretical levels.

Unquestionably, the invention of written symbols to represent spoken language was a great achievement in the history of mankind. With the advent of writing, communication was expanded and the limitations of space and time (which are usually imposed upon oral communication) were overcome. There have been many writing systems for many different types of spoken languages. The basic design principles can be divided into two different categories: (1) A category including a progression from the early semasiography, which expresses a general idea in picture drawings rather than a sequence of words in a sentence, to logographs with each symbol expressing a single particular morpheme. The concept underlying the development of this type of orthography is to map the written symbols directly onto meaning; and (2) a category of writing sy tems including a progression from the rebus system (a representation of a word or phrase by pictures that suggest how it is said in the spoken language, e.g.,



for idea) to syllabaries and, finally, to the alphabet. The concept behind this type of orthography is sound writing. Undoubtedly, the evolution and persistence of a certain type of writing depends to a great degree on the special characteristics of its corresponding spoken language (a review of the development of various types of writing systems can be found in Hung & Tzeng, 1981). Since spoken languages differ considerably, diversity in writing systems is to be expected.

The diversity of .ting systems raises the important question of whether the acquisition of reading skills is facilitated or hindered by how the spoken language is represented in print. Th's question has become

of major concern among reading specialists (e.g., Gibson & Levin, 1975; Gleitman & Rozin, 1977; Liberman, Liberman, Mattingly, & Shankweiler, 1980) as well as among cognitive psychologists who are interested in the effect of orthographic differences on visual information processing (Biederman & Tsao, 1979; Chu-Chang & Loritz, 1977; Park & Arbuckle, 1977; Lukatela & Turvey, 1980; Tzeng & Hung, 1980; Tzeng, Hung, & Garro, 1978; Tzeng, Hung, & Wang, 1977). It is not unreasonable to conjecture that human information processing strategies may differ because the information is presented in different formats. For example, it has been suggested that the meaning of words and of pictures are recovered via different processing routes (Paivio, 1971). Thus, depending upon how meanings are represented in print (i.e., what type of writing system is used), a reader may have to develop different processing strategies in order to achieve reading proficiency. By comparing the experimental results of reading behavior across languages as well as across different writing systems, we should be able to gain some insights into the various intricate processes involved in reading.

With the assumption that different orthographies may encourage the use of different processing strategies (in fact, Hung & Tzeng, 1981, provide much needed empirical evidence to support this assumption), we can easily appreciate the general value of cross-language and cross-writing-system studies. We can learn about the range of possibilities in terms of processes that are used to read and to learn to read in each writing system by studying each of these processes. Knowledge of the possible reading processes would also contribute to the establishment of new theories of cognitive processes from reading research (e.g., Morton's logogen model, 1969). It would also have valuable applications in such instances like the modification of orthographies (Grimes & Gordon's discussion of problems encountered in constructing written languages for many American Indian languages, 1980). Furthermore, delineating the similarities and differences of reading processes between different writing systems will help build an efficient reading instruction program which will benefit those bilingual children (recent refugees and

other language minority children) who are initially or simultaneously taught to read in writing systems other than English orthography. With these general statements in mind, let us now examine various grapheme-speech mapping relationships embedded in different types of orthographies and see how much orthographic variations affect the processing strategy of both beginning and fluent readers.

Relations Between Script and Speech

The relationship between written scripts and spoken languages seems so close that it would be expected that anyone who is able to speak should be able to read. This is simply not so. For all normal children, spoken language requires no special effort to learn. On the other hand, learning to read requires a relatively long period of special training and depends heavily on intelligence, motivation, and social-cultural factors. Two psychologists of reading have summarized the state of affairs by saying, "The problem wih reading is not a visual perceptual problem; the problem is rather that the eye is not biologically adapted to language" (Gleitman & Rozin, 1977, p. 3).

There is consensus that written languages evolved much later than spoken languages and that, in some way, the former attempted to mimic the latter. Except for the earlier semasiography (dating back at least as far as 20,000 B.C.) which used pictorial representations to refer to meaning directly, most writing systems of the world today are derivative, in various forms, of their corresponding spoken language. Since their development is largely based on speech, the scripts are all correlated with the pre-existing units of the spoken languages. The exact nature of this correlation varies across languages. That is, since there are many levels of representation for a spoken language, the transcription of visual symbols into the spoken language can be achieved in many different ways. Let us examine these relations more closely.

Linguists commonly recognize three classes of phonetic segments: Phones, phonemes, and morphophonemes (in order of increasing abstractness). The segments are grouped together horizontally into larger sequences forming the mora and the syllable. These distinctions can be seen in the Japanese kana script, as illustrated clearly in the chapter of Wang (this volume). The point to be emphasized is that different writing systems map their graphemic symbols onto these various levels of speech units. Consequently, the numbers and the nature of graphemic symbols vary from one type of writing systems to another, resulting in different degrees of orthographic complexity.

These different script-speech relations have important psychological implications for the learner. Recent speech perception research indicates that syllables are the smallest coherent units of speech: They tend to be physically undissectible, they are the smallest pronounceable units of speech, and they may be produced in preplanned units (Liberman, 1970). Therefore, grapheme-speech mapping at the syllable level should be less abstract than that at the level of moras or at the level of phonemes. Moreover, it has been reported that few reading disability children are observed in writing systems with concrete script-speech relations such as the Japanese syllabaries and Chinese logographs (Makita, 1968; Tzeng & Hung, 1980) in which every character also represents a single syllable.

The traditional classification of orthographies into logographic, syllabic and alphabetic modes captures three types of script-speech mapping relations. For present purposes, we will review the essentials of these relations; however, a detailed and in-depth analysis of such relationships can be found in Hung and Tzeng (1981; see also Wang, in this volume).

A look at the history of these three types of writing systems reveals that their development proceeds in a certain direction: In a sense, the transcription initially starts at the deepest level, the conceptual gist (e.g., picture drawings), then gradually shifts outward to the surface

level, the sounds. At each step, the unique and concrete ways of representing meaning give way to a smaller but more general set of written symbols. In other words, the efficiency of writing is achieved at the cost of sacrificing the more direct link to the underlying meaning, and consequently, the grapheme-meaning relation becomes more and more abstract. It is also important to note that for every language the resulting writing system to a large extent depends on how that system fits the structure of its spoken form. For example, without logographic symbols, both Chinese and Japanese would have tremendous difficulties in handling the problems of excessive homophones in the spoken units.

Logography represents speech at the level of the morpheme rather than the word, so that each logogram stands for the smallest meaningful unit, and its form, therefore, remains constant regardless of syntactic structure. That is, grammatical marking elements, such as tense, number, gender, and so on, are introduced by adding other morpheme characters rather than modifying the form of a particular character. For example, in Chinese logographs, "go," "went," and "gone" are expressed by exactly the same character 去 , and both ox and oxen are expressed by the single character, 牛 . Essentially, the non-inflective nature of the Chinese spoken language makes it easy for Chinese scholars to adopt a writing system based upon logographic principles. Thus, "a character is a character is a character" in the Chinese writing system. This perceptual constancy must provide a certain advantage over those writing systems, such as the English alphabet, which require the marking of grammatical inflections at the morphological level. Thus, initial learning success of a logographic system depends upon the distinct differences between the characters to be learned. As more characters are introduced, however, similarities to the previously learned characters are bound to be perceived (after all, there are only eight basic strokes in Chinese character formation). Whatever initial cues a young reader uses tends to fail as more characters are learned; confusion arises, and learning is disrupted until other mnemonic devices can be used (Samuels, 1976).

The syllabary represents speech at the level of the syllable, a perceptually identifiable unit with a reduced set of symbols. For a beginning reader, the match between each symbol and each perceived sound makes the translation of visual arrays into the speech code much easier. The concept of mapping the secondary linguistic activity (i.e., reading) onto the primary linguistic activity (i.e., speech) can be acquired earlier through direct perceptual-associative links. However, the initial success of learning a syllabary starts to collapse as soon as a large number of lexical items are learned and the problem of homophones sets in. For example, confusions over segmentation (corresponding examples of English would be to-gether vs. to-get-her; a-muse vs. am-use, etc.) tend to pile up during ordinary reading (Suzuki, 1963). Special processing strategies are required with great demands on the reader for the linguistic parsing of a syllabary text (Scribner & Cole, 1978).

Finally, an alphabetic writing system represents speech at the morphophonemic level such that the grapheme-sound-meaning relationship is opaque. This requires a highly analytical processing strategy to disengage the meaning encoded in words that are composed of a still further reduced set of symbols. The abstractness of such a multi-level representation may be optimal for fluent readers (Chomsky & Halle, 1968). However, it poses considerable difficulty for those beginning readers whose cognitive ability has not yet reached the level necessary for extracting the orthographic regularities embedded in the written words.

There is also an important contrast between logographic and alphabetic scripts with respect to how symbols are stacked together to represent the spoken language graphically. Again, Wang (this volume) has made this contrast very clearly in his chapter. He cogently pointed out that in English script, spaces are largely determined on the basis of words, while in Chinese script, the spacing is based on morphemes, and each morpheme is in fact a syllable. Perceptually, the grapheme-sound mapping in Chinese is discrete while in English script the relation is continuous and at a more abstract level.

Such a difference in the grapheme-sound mapping in these two languages may have different implications for the beginning readers of these two scripts. For Chinese children, the written array is dissected syllable by syllable and thus has a one-to-one correspondence with the syllabic boundaries of the spoken language. Because of the multi-level representation of English, however, a reader of English may have to go through a morphophonemic process in which (a) words are first parsed into morphemes and then (b) symbol-sound relationships applied (Venezky, 1970). Furthermore, phonological rules are necessary in order to derive the phonetic form (e.g., to get /sain/ for sign). These processes are very abstract and may, therefore, be quite difficult for the beginning reader.

As we examine these historical changes, we see that the evolution of writing systems follows a single developmental pattern. With every advance, the number of symbols in the script decreases and, as a direct consequence, the abstractness of the relationship between script and speech increases. This pattern of development seems to parallel the general trend of cognitive development in children. Results from two independent lines of research are of particular interest. First, anthropological studies (Laboratory of Comparative Human Cognition, 1979) have shown that children's conceptualization of the printed arrays in a text proceeds from pictures to ideas, to syllables, and finally, to "wordness." Second, according to E. Gibson (1977), one of the major trends in children's perceptual development is the increasing specificity of correspondence between what is perceived and the information in stimulation, as a beginning reader progresses from the whole to the differentiation of the whole, and then to the synthesis of the parts to a more meaningful whole.

In a sense, the ontogeny of cognitive behavior seems to recapitulate the evolutionary history of orthographies. Certainly, this cannot be simply a biological coincidence (Gleitman & Rozin, 1977). Such parallelism implicates the importance of a correspondence between the

cognitive ability of the reader and the task demand imposed by the specific orthographic structure of the scripts. One is almost tempted to suggest that orthographic structure in a writing system must somehow mold the cognitive processes of its readers. In fact, it has been claimed that the processes involved in extracting meaning from a printed array depend to some degree on how the information is represented graphically (Besner & Coltheart, 1979; Brooks, 1977; Tzeng & Hung, 1981).

It is conceivable, therefore, that different cognitive strategies are required to achieve reading efficiency in various writing systems. One particular concern is whether these different cognitive requirements imposed by various script-speech relations impose a permanent constraint on our visual information processing strategies, such that readers of different scripts learn to organize the visual world in radically different ways. Evidence for such a new "linguistic relativity" hypothesis can be found in papers discussing the "weak" version of the so-called Whorfian hypothesis (Tzeng & Hung, 1981) and in recent ethnographic studies on the behavioral consequences of becoming literate in various types of Vai writing systems (Scribner & Cole, 1978). Cross-language and cross-writing system comparisons are certainly needed to help us answer this and other questions.

Orthographic Variations and Cognitive Processes

We have reviewed the general background for the development of various types of written scripts. We have also briefly discussed the linguistic status of each of the three major types of orthographies in terms of its embedded script-speech relationship. Let us now turn our attention to the behavioral consequences of these variations. There are many issues which have recently been tackled by cognitive psychologists, anthropologists, and by neurolinguists. Among them, our concern will focus on those having to do with bilingual literacy.

1. Reading Disability. While the problem of reading disability is pervasive in languages adopting the alphabetic principle (e.g., English, German, Spanish, etc.), the rarity of reading disability at the beginning level has been noted in languages adopting syllabic and logographic systems (Makita, 1968; Tzeng & Hung, 1980). Makita attributes the success of Japanese initial reading instruction to the fact that kana scripts have one-to-one grapheme-sound correspondence. Sakamoto and Makita (1973) further show that many Japanese children learn kana symbols without formal instruction before they enter school.

On the other hand, Tzeng and Hung attempt to account for the success of Chinese instruction in terms of linguistic considerations. They point out that Chinese, as a logographic script, is meant to express a single particular morpheme while ignoring many grammatical marking elements (e.g., I WANT GO instead of I WANTED TO GO). That is, the character remains the same regardless of syntactical changes. In Chinese, the character-speech mapping is morphosyllabic in nature. Thus, for Chinese children the task of learning to read simply means learning how to associate each spoken syllable with a particular character of a designated meaning. In general, the orientation and the number of strokes which form the basis of a character bear no relationship to the sound of the spoken word. Even though the majority of modern Chinese characters are phonograms (Wang, 1981), the success rate of using a base character to sound out another character is estimated to be low (less than 39% according to a recent analysis of Zhou, 1978). This lack of symbol-to-sound correspondence gives the beginning readers a straightforward way (and probably the only way) to master thousands of distinctive characters through rote memorization. This situation is very different from that of learning an alphabetic script where one has to be able to extract orthographic regularities embedded in written words in order to figure out the letter-sound correspondence rules. Therefore, beginning readers of Chinese (when the number of characters to be memorized is still limited) face a more concrete learning situation than those who are learning the alphabetic writing system. The ease of

acquisition of the logographic system was manifest in the widely cited study in Philadelphia with a group of second-grade school children with serious reading problems. These children continued to have problems even after extensive tutoring by conventional methods but were able to make rapid progress in learning and reading materials written in Chinese characters (Rozin, Poritsky, & Sotsky, 1971).

While the evidence appears impressive, one should be cautious in interpreting results reported in the above studies. The study reported by Makita (1968) and the one cited in Tzeng and Hung (1980) were both crude survey reports. Questionnaires were sent to school teachers and predesignated questions were framed in a manner far from satisfactory. Moreover, in both Japan and Taiwan where literacy is highly valued and a great deal of social pressure is always imposed upon schools to make the schools look good, a simple survey on reading disability can never tell the whole story. For one thing, Makita claimed that kana is easy to learn because it maps onto the sound at the level of syllable. However, linguistic analysis shows that kana in fact maps onto the sound at the level of mora (Wang, 1981), a smaller but more abstract unit than the syllable. Furthermore, there is a report that Japanese children do have problems dealing with mora (Sakamoto, 1980). However, different countries have different criteria for reading disability. Thus, evidence such as that provided by Makita and by Tzeng and Hung, without appropriate cross-cultural control, cannot be interpreted too enthusastically. Rozin et al.'s (1971) data is interesting, but methodological weaknesses make it less impressive than at its first appearance. Other criticisms have been advanced in Tzeng et al. (1977). It is important to get one thing straight: Learning a limited number of Chinese characters does not qualify a person as a successful learner of Chinese. The essential difficulty of learning Chinese scripts lies in its huge number of distinctive characters. Rozin et al.'s success in teaching second-grade non-readers in English to read "first" grade or lower materials in Chinese is hardly surprising.

I think it is fair to say that so far no hard evidence has been provided to support the rarity of reading disability in a certain type of orthography as compared to other types of orthographies. However, at different stages of acquisition, learning seems to be impeded by different kinds of difficulties. This is not surprising. Readers of a logographic script must face the problem of memorizing a vast amount of distinctive characters. Readers of a syllabary must search for invariances at one level while readers of an alphabetic system still another level. The commonality is that learning to read effectively is dictated by the special script-speech relation embedded in a particular orthography. It is no wonder that the linguistic awareness of one's own language becomes a prerequisite condition of successful learning in the beginning readers. This is especialy true in the alphabetic scripts with deep phonology (such as English, see Liberman, Liberman, Mattingly, & Shankweiler, 1980; Mattingly, 1979).

2. Neuropsychological Difference. We know that in Japanese three different types of scripts (four if the prevalent use of romaji is considered) are used to represent text. A fluent reader of Japanese has to know all three types of scripts, namely, kanji, katakana and hiragana). Sasanuma and her associates (for a more detailed review of Sasanuma's work, see Hung & Tzeng, 1981) have presented evidence showing that the ability of Japanese aphasic patients to use kanji and kana scripts may be selectively related to the specific type of aphasic disorder. Careful examination of the patients' performance suggested that impairment of kana processing typically occurred in the context of the overall syndrome known as Broca's aphasia, while impairment of kanji was characteristic of Gogi (word meaning) aphasia. The implication is that phonetic-based scripts such as kana and logographic-based script such as kanji require different brain location in their visual information processing. But this structural interpretation may not be necessary. Empirical research with Chinese characters by Tzeng et al. (1977) and the on-going research into the relationship between reading and speech by the Haskins' group (Liberman et al., 1977) point to the importance of the auditory short-term

store as necessary to primary linguistic activity such as comprehension, and that morphological information may require phonetic storage at an intermediate stage of processing. The results reported by Sasanuma and her associates may be interpreted not as independent neural processing of the phonetic and morphemic components, but as differential realization of two levels of linguistic awareness (Erickson, Mattingly, & Turvey, 1977). Although clinical evidence such as the above case has its limit in generalizability, the observation of selective impairment in reading kanji and kana scripts among the Japanese aphasic patient nevertheless demonstrates differential task demands imposed by these two scripts.

Sasanuma's (1974) findings quickly prompted another series of research which is concerned with whether the visual lateralization effect (i.e., hemispheric dominance) would show differential patterns, depending on whether phonetic scripts (e.g., Japanese kana, English alphabet, etc.) or logographic scripts (e.g., Chinese logographic and Arabic numerals) are used as stimuli. The term "lateralization" refers to the different functions of the left or right cerebral hemispheres Mishkin and Forgays (1952) tachistoscopically exposed English words to either the right-visual-field (RVF) or left-visual-field and found a differential accuracy of recognition, favoring words presented to the RVF, suggesting a left hemisphere superiority effect.

On the other hand, research investigating wnether the asymmetric visual field effects are subject to the influence of variations in the orthographic structure generally reports a different pattern. For instance, processing Yiddish words has been found to show a left visual field advantage, and the habit of visual scanning during reading was suggested to assume an important role in the visual half-field experiment.

The unique styles of kanji and kana symbols provide a testing ground for theories of cerebral organization. Hirata and Osaka (1967) and Hatta (1976) both found a superior performance of the left hemisphere in the processing of kana symbols. This result is similar to those obtained with

alphabetic writing. Recently, Hatta (1977) reported an experiment measuring recognition accuracy of kanji characters and found a LVF (right hemisphere) superiority for both high and low familiar kanji characters. Also using a recognition procedure, Sasanuma, Itoh, Mori, and Kobayashi (1977) presented kana and kanji words to normal individuals and found a significant LVF superiority for the recognition of kana words but a nonsignificant trend of LVF superiorty for kanji characters. Thus, it seems that for those sound-based symbols such as English words and Japanese kana scripts, a RVF-LH superiority effect is to be expected in a tachistoscopic recognition task while a LVF-RH superiority effect is to be expected for the recognition of kanji logographs.

Controversy arises immediately concerning the reliability of the kanji effect. Previous experiments conducted by Kersner and Jeng (1972) as well as by Hardyck, Tzeng, and Wang (1977) with Chinese reported significant RVF superiority effect in the processing of Chinese characters. Thus, the cerebral orthography-specific localization hypothesis proposed by Hatta (1977) is questionable. A recent study by Tzeng et al. (1979) sheds light on this issue. They found that, in fact, the LVF superiority was only obtained with recognition of single characters; a RVF advantage similar to that obtained with alphabetic materials was observed when two or more characters which make up a linguistic term were used. Tzeng et al. interpreted these differential visual lateralization effects as reflecting the function-specific property of the two hemispheres and rejected the orthography-specific localization hypothesis. This interpretation was further supported by Elman's (1981) results that even with single characters, only the simple naming task showed a LVF right hemisphere dominance; a more complicated grammatical classification task showed a left hemisphere dominance. Therefore, the evidence for differential brain functions in processing phonetic-based and logographic scripts does seem to be strong so far as these functions are interpreted with respect to differential demands imposed by the scripts.

So far, I have briefly reviewed research on effects of orthographic variations on cerebral lateralization using two different approaches, namely, the brain lesion approach and the visual half-field experimental approach. It is true that differences were found in the clinical and experimental studies resulting from reading different orthographies. One may want to interpret these data as supporting the hypothesis of hemispheric specficity. However, Hung and Tzeng (1981) offer an alternative interpretation in terms of differential knowledge structures. According to them, the two different pattern-analyzing skills (i.e., recognizing kanji vs. kana scripts) may be viewed as reflecting two different types of acquired knowledge, namely, knowing that versus knowing how. The former represents information that is data-based or declarative, whereas the latter represents information that is based on rules or procedures (Kolers, 1979). According to Mattingly (1972), operations with these two types of knowledge require two different levels of "linguistic awareness." Whereas the realization of knowing that requires only a primary linguistic activity, the realization of knowing how requires a more abstract secondary linguistic activity. The imbalance between kanji and kana impairments observed in Japanese aphasics (Sasanuma, 1974) may be the result of differential difficulties related to the performance of these two levels of linguistic activities. The dissociation of knowing how and knowing that has recently been demonstrated in amnesic patients (Cohen & Squire, 1980). This being the case, then the disproportion of kanji-intact and kana-intact aphasic patients can be interpreted from the viewpoint of two different levels, of complexities involved in the two types of knowledge structures.

In neuropsychological research, specification of brain functions in the right and left hemispheres is important. But cautions should always be exercised against sloppy procedures and over-anxious conclusions. Due to their unique formation, Chinese characters offer extremely important opportunity for investigators to examine the different properties of the two hemispheres. However, it is essential that the investigation must start by analyzing the linguistic property of the characters. A recent

study by Nguy, Allard and Bryden (1980) "demonstrated" that Chinese "pictorial" characters show a different pattern of lateralization effect in visual half-field experiments as compared to non-pictorial characters. A careful examination of their materials and their unconventional classification show only that their data are totally unsubstantial. For example, how can the character for "ghost" be pictorial unless they are seeing a ghost? Such careless experiments have to be avoided.

3. Differential Processing Mechanisms and the Behavior Consequences. The question as to whether different processing mechanisms are activated in reading different scripts and if the behavioral consequences of being literate in varous writing systems differ are concerns currently confronting researchers. With respect to the first question. Besner and Coltheart (1979) have provided positive answers by showing that making quantative comparisons between two numbers may engage different processing mechanisms depending upon whether these numbers are presented in Arabic (logographic symbols) or in spelled-out English letters. Their data showed that size incongruency interfered with attempts to assess Arabic number for quantative value. When the numbers were spelled-out, however, no interference was manifest. Similar size incongruence interference occurs in a comparative judgment task (Paivio, 1975) when the two to-be-compared items are presented in pictorial form but not in spelled-out words. The conclusion from these results is that different lexical retrieval routes are activated in order to perform the task of making a comparative judgment (Paivio, 1975). Thus, depending upon how meanings are represented in print, a reader may have to develop different processing strategies in order to achieve reading proficiency.

To tap into these different processing mechanisms, Turnage and McGinnies (1973) asked Chinese and American college students to study a 15-word list in a serial learning paradigm. They also manipulated the input modality of the stimulus presentation. It was found that Chinese students learned the character-list faster when it was presented visually whereas American students learned the word-list faster when it was

presented auditorily. The finding on the Chinese characters is opposite to the famous modality effect (Crowder, 1978) in which auditory presentation of English words results in better recall than does visual presentation. The interpretation offered by Turnage and McGinnies (1973) is that Chinese logographs contain more characters with similar sounds but different meanings than is the case for English, and this characteristic of the orthographic structure may favor learning through the visual mode.

Turnage and McGinnies' (1973) study involved two different language populations. Not only were the scripts different, there was also a difference in spoken language. The script may not be the determinant factor; rather, the visual modality advantage could have been a result of differences in spoken languages. But this latter account was soon ruled out by a study comparing the learning rate of Korean words written in either Chinese characters or Korean hangul (an alphabetic script, see Wang, 1981). Koreans can transcribe their spoken language in either script. Park and Arbuckle (1977) examined the memory of Korean subjects for words written in these two types of writing systems and found that words presented in logographic script were remembered better than words presented in alphabetic script on recognition and free recall but not on paired-associate recall or serial anticipation. Thus, there is indeed an intrinsic difference with respect to the processing mechanism for these two scripts, and these differences seem not to be associative in nature.

The most impressive line of research so far has been provided by Scribner and Cole (1978) in their ethnographic study of the cognitive consequences for tribal Vai adults of becoming literate in Vai or Arabic. An analysis of the process of reading the Vai syllabary indicated that special task demands are imposed by the script. Vai is a tone language but tonal information is not marked in the script. Furthermore, no word boundaries or punctuation are indicated in writing a text so that the reader must group the syllables together to form words, then again integrate these into meaningful linguistic units. On the other hand, the Arabic script is an alphabetic system and is learned mainly through a rote

memory process (the students don't understand or speak Arabic). When students of these two rather different scripts were tested in various cognitive tasks, Vai and Arabic literates did not differ in their ability to comprehend the word strings, but Vai literates were superior on the picture reading and syllable integration tasks which mimicked their normal reading activities. In contrast, Arabic literates performed better than Vai literates on the incremental memory task which presented task demands most similar to their everyday reading activities. These results indicate not only that different scripts impose different task requirements for achieving proficiency, but also that strategies developed to meet these requirements are transferable to situations with similar task requirements. Therefore, Scribner and Cole (1978) provide rather strong evidence for our hypothesis that becoming literate in certain scripts can have a long lasting effect in molding our information processing system.

4. Speech Recoding in Reading. When people read to themselves, do they recode the visual input into some sort of speech-like code (i.e., articulatory, acoustic, or both)? The existence of such recoding is no longer in doubt (Baron & Treiman, 1980; Tzeng & Hung, 1980). The question now facing us is why. What factors encourage its use and what factors discourage it? Orthographies vary considerably in the demands on the reader. According to Liberman, et al. (1980), one of the aspects of such variations is the depth of the orthography, which can be defined as the relative distance between an orthography and its phonetic representation. For example, compared with Vietnamese, English is a rather deep orthography, and thus demands greater phonological development on the reader's part. It is quite possible that differences in orthographies along this dimension affect the use of speech recoding in silent reading. If the written forms on the page stand in a regular relationship to the sounds of language, the reader may use the grapheme-sound rules to help him derive the meanings of words. Such a path would be largely unavailable to the reader of Chinese, but would be highly available to English readers. Therefore, we would expect readers of English to engage in speech recoding more than would Chinese readers (Chu-Chang, 1977).

Such an expectation was recently verified in a study conducted by Treiman, Baron, and Luk (1981).

The investigation into the relationship between the degree of speech recoding and the depth of orthography is an important one. By finding differences among orthographies along the dimension of grapheme-sound regularity, we can convince ourselves of the existence of some speech recoding in at least one of the orthographies studied. For example, Treiman, Baron, and Luk's (1981) finding that more speech recoding occurs in alphabetic than logographic scripts (as indexed by longer reaction times and/or more mistakes in judging homophone sentences) enables us to conclude that some speech recoding does occur in reading alphabetic scripts. Once this fact is established, we can begin to provide accounts of the possible pathways (causal links among mental representations) between representations of print, speech, and meaning. For researchers who attempt to build cognitive models in terms of reading behavior, knowing the effect of the orthographic structure on the relations of these pathways should be one of their ultimate goals. So far, we know that whether or not a certain path will be bypassed or activated depends on the orthographic structure of the script one is reading. But the precise relationships are still far from clear.

One can push the argument even further and make the claim that, in an alphabetic script where the prediction of sound from letters alone is always valid (i.e., a perfect spelling-to-sound regularity), readers may automatically activate the phonological route to the lexicon. Experiments with a "phonologically shallow" orthography such as Serbo-Croatian (the major language of Yugoslavia which can be written in either Roman or Cyrillic) have consistently demonstrated that lexical decision proceeds with reference to the phonology (Lukatela, Popadic, Ognjenovic, & Turvey, 1980). Most importantly, these investigators found that even when matters were arranged so as to make the use of a phonological code punitive in accessing the lexicon, readers of Serbo-Croatian were unable to suppress the phonological code. This result is directly opposite to that obtained

in English. Davelaar, Coltheart, Besner, and Jonasson (1978) found that under similar arrangements readers of English abandoned the phonological route and opted for direct visual access to the lexicon. Thus, in a less shallow orthography such as English, reading may proceed simultaneously at several levels of linguistic analysis. The concept of depth with respect to the orthographic structure seems to be a useful construct in evaluating the issue of speech recoding. Here is an area in which comparative reading studies across different orthographies can yield important information.

Why do experimental psychologists concerns themselves about the issue of speech recoding? Besides the purely intellectual implications, there are reasons of practical importance. For one, it relates to the choice of teaching methods. There are currently two popular methods of teaching a six-year-old child how to read. On the one hand, there is the phonics methods which emphasizes learning the sound made by letters first, then learning to blend these sounds so that the written symbols make contact with their meanings through the spoken language. On the other hand, there is the whole-word method which emphasizes learning a direct connection between the written word (as a visual pattern) and the meaning for which it stands. Thus, depending on his/her attitude about the presence or absence of speech recoding during reading, the teacher decides whether the phonics or the whole-word method is a more appropriate one for teaching young children how to read.

The second practical reason for our concern about the issue of speech recoding is that of dialect-mismatch between teachers and a bilingual child (or for that matter the inner-city school children in this country). It is a common observation that in many bilingual classes the spoken language of teachers contrasts sharply with that of the students. In learning to read, the consequence of such a mismatch can be a serious one (Chu-Chang, 1979). What should the teacher do? Only by examining the issue of speech recoding in reading will we be able to come up with some

suggestions. For now, it is important that we call attention to this issue (Chu-Chang, 1979).

5. Bilingual Processing. Our final issue concerns research in bilingual processing. In the past, bilingual studies have always dealt with spoken languages. There has been little concern with the possibility that experimental results may be contaminated to various degrees by variations in the orthographic structure. Recently, Biederman and Tsao (1979) reported a study in which they found that orthographic variations have substantial effects on bilingual processing. In this study, a Stroop-color-naming task[1] (Stroop, 1935) was employed as the experimental paradigm and a Chinese version and an English version were developed for the Chinese and American subjects, respectively. The results showed that a greater interference effect was observed for Chinese engaging in a Chinese-version Stroop-color naming task than for American subjects in an English-version. They attributed this difference to the possibility that there may be fundamental differences in the perceptual demands of reading Chinese and English.

Prompted by the intriguing finding of Biederman and Tsao (1979), Fang, Tzeng, and Alva (in press) went one step further and ran a modified version of the Stroop experiment. They asked Chinese-English bilinguals to name colors in either Chinese or English on either a Chinese version or an English version of the Stroop test. They found a reduction of the interference effect in the inter-language condition (i.e., responding in Chinese on the English version or vice versa) as compared with that in the intra-language condition. A similar experiment was performed using

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[1] In studies of the Stroop effect (Stroop, 1935), color names are written in an ink of a different color (e.g., green is written in red ink) and subjects are required to name the color of the ink in which the word is written. In the control condition, subjects name the colors of a series of different color patches. It is an established fact that the time it takes to name a series of colors in the test condition is much longer than the time it takes to name a series of color patches in the control condition.

Spanish-English bilinguals with either English version or Spanish version Stroop test. Again the reduction of the Stroop interference was observed in the inter-language condition as compared to the intra-language condition. A further analysis reveals that although both experiments showed a reduction of interference in the inter-language condition, the magnitude of reduction was greater in the Chinese-English experiment than in the Spanish-English experiment. Since Spanish and English are both alphabetic scripts, switching languages does not change the processing demands. However, since English and Chinese represent two different orthographic structures, switching from one to the other may prevent subjects from employing the same processing mechanism and consequently cause them to be released from the Stroop effect.

Fang et al. (in press) also made an interesting observation. They recalculated from Dyer's (1971) and Preston and Lambert's (1969) bilingual data the magnitude of reduction of the Stroop interference from the intra- to the inter-language condition. Altogether, there were six types of bilinguals, namely, Chinese-English, Japanese-English, French-English, German-English, Hugarian-English, and Spanish-English bilinguals. Frang et al. ranked these bilingual data according to the magnitude of reduction from intra- to inter-language condition. The result is as follows: Chinese-English, Japanese-English (with kanji), Japanese-English (with kana), Hungarian-English, Spanish-English, German-English, and French-English. This ordering suggests that the magnitude of reduction (from intra- to inter-language) depends on the degree of similarity between the orthographic structures of the two tested languages. Thus, bilingual processing is definitely affected by the orthographic factor, and (it is fair to say that) the curious neglect of the orthographic factor in previous bilingual research is an unfortunate mistake. For example, there has been a debate among researchers of bilingual processing on the issue of whether bilinguals represent their two languages in two

virtually independent lexica or in two inter-dependent lexica (or even a single lexicon). To the extent that the orthographic varition plays an important role in a lexical decision task (Meyer & Ruddy, 1974), how can we resolve the independent versus inter-dependent lexica issue without taking into account variations in the orthographic structure?

From the viewpoint of cross-language research, the demonstration of the importance of the orthographic factor raises a host of more intricate questions to be answered. Do these differences, for instance, result in different types of dyslexia? Do they necessitate different instructional strategies for teaching different scripts to beginning readers? To readers learning a second language which has a different orthographic structure?

Conclusion

There is an inseparable relationship between written language and spoken language--both are essential communications tools in human societies, and to some extent, the former is derived from the latter. There are many writing systems for many different languages. Essentially, they can be categorized into three basic writing systems based upon their various grapheme-meaning relationships: Logographic, syllabic and alphabetic writing systems. The present paper has reviewed most of the empirical work which is relevant to the issue of bilingual literacy. I have tried to characterize differences of cognitive processes in reading different types of orthographies. The recognition that different orthographic structures impose different task demands is an important one. Without such recognition and an attempt to control the orthographic factor, cross-language comparisons of literacy skills are meaningless.

In the past, research in bilingual education and bilingualism has made an implicit, but incorrect, assumption that all bilinguals, regardless of the type of orthography in the original language, are alike. Research reviewed above has shown that reading skills acquired in one

orthography may not be the same as those acquired in another orthography, if these two orthographies have different script-speech mapping rules. Thus, instructional programs for bilingual children whose home language has a non-alphabetic orthography should be carefully designed to facilitate positive transfer and minimize negative interference due to the orthographic factor.

Comparative reading research across different languages is an important task for it will help us to "unravel the tangled story of the most remarkable specific performance that civilization has learned in all its history" (Huey, 1908, 1968, p. 6).

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